Lean Construction and BIM in Small and Medium-Sized Enterprises (SMEs) in Construction: A Systematic Literature Review

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Abstract

Lean Construction (LC) and Building Information Modeling (BIM) are two of the prominent concepts challenging the traditional practices in construction management. Small and medium-sized enterprises (SMEs) often constitute the largest group in construction supply chains. Increasing BIM and LC adoption amongst SMEs is a key condition for achieving the transformation of the construction industry through BIM and LC. The paper presents a systematic literature review of the adoption of (i) LC, (ii) BIM, and (iii) both LC and BIM in SMEs to evaluate the current literature. 114 papers were included in the review. The bibliographic and content characteristics of the literature were discussed in detail. It was found that despite the importance of SMEs, the current LC and BIM literature falls short in terms of both number of publications and content of publications. The paper concludes with some generic suggestions for future research and action.

Keywords: state-of-the-art review, BIM, Lean Construction, SMEs, Construction management

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1. Introduction

The construction industry in most countries is categorised by a small number of larger companies and a very large number of small and medium enterprises (SMEs). In many cases, larger firms prefer not to retain a large employee base and sub-contract work to smaller sub-contractors (Dubois et al. 2000; Green et al. 2005; Fulford and Standing 2014). In smaller projects, an SME can often be the main contractor or developer. For example, in the United Kingdom (UK), in the third quarter of 2016, there were 296,093 companies classified as being in the construction industry. Of these, only 147 employed in excess of 300 people. Of the remainder, the majority employed fewer than 5 people (Office of National Statistics, 2017). Trani et al. (2014) provide similar figures for Italy, showing that from nearly 600,000 construction firms, only 84 are large. The clear majority are small or micro enterprises. Loforte Ribeiro and Timóteo Fernandes (2010) suggest that over 99% of all construction companies in Europe are SMEs that mostly employ fewer than 10 people. In 2015, 92% of all 669,227 construction enterprises in the USA were classified as small enterprises (United States Census Bureau 2018). Data for Q2 (2018) show that 1,014.553 people were employed in construction occupations in Canada. Of these, only 127,098 (circa 12.5%) worked for organisations with greater than 500 employees (Canadian classification as large enterprise) Circa 73.1% worked for organisations with fewer than 90 employees (Canadian classification as a small enterprise) (Statistics Canada 2018).

Definitions for SMEs are not uniform throughout the world. A commonly used definition is that used by the European Union (EU). Accordingly, a small company is defined as having fewer than 50 employees, whilst a medium sized company has between 50 – 249 employees. A micro company is usually defined as employing fewer than 10 people. (European Commission 2018). For the purposes of EU funding applications, financial assets are also

considered. The turnover of medium companies (50-249 employees) should not exceed €50 million, whilst turnover of small companies (10-49 employees) should not exceed €10 million (European Commission 2018). Statistics Canada (2015) define SME as: Small enterprise having 1 – 99 employees; Medium enterprise having 100 – 499 employees; and, large enterprise having greater than 500 employees.

There is typically no particular heterogeneity within construction industry SMEs. Some SMEs in the industry provide specialist services and may have a significant capacity and expertise in areas such as information technology and specific construction tasks. Others, particularly those at the coalface, may not (Dainty et al. 2017). Construction industry SMEs are affected by their sectors' (e.g. building, civil, industry etc.) supply chain characteristics (Tezel et al. 2018) and their large clients' strategies (Kheni et al. 2008; Hardie and Newell 2011). Lundkvist et al. (2010) note potential difficulties in sampling SME firms for research, finding that the limited staff resources available within SMEs, made both random sampling and solicitation of responses to questionnaires and other surveys difficult, particularly in smaller firms. Teck Heng Lim et al. (2010) excluded from their study small construction companies in Singapore, claiming that they typically worked as sub-contractors, and so had different perspectives from medium or large companies.

Two important concepts that have been developing since the 1990s will potentially have significant impacts in the delivery of construction projects; namely Building Information Modeling (BIM) (Zhao 2017; Antwi-Afari et al. 2018) and Lean Construction (LC) (Dave et al. 2016; Sarhan et al. 2017). The term 'Building Information Modelling (BIM)' was first introduced into the industry in the early 2000s, from a buzzword coined by a software manufacturer with early adopters (Dainty et al. 2017) and can be defined as a product, an

activity or a process (Eastman et al. 2011). The wider view of BIM as a process encompasses creating and using a digital representation of a building or project, an object-orientated 3D model with its geometric and attribute data, or a repository of project data, through the project life-cycle (Eastman et al. 2011). BIM also engenders the potential for wider and deeper collaboration between stakeholders (Miettinen and Paavola 2014). The claimed benefits from BIM are extensive: (i) speeding up the design and build process; (ii) easier sharing and reuse of data; (iii) better designs via rigorous assessment; (iv) accurate prediction of environmental and life-cycle data; (v) improved production quality; (vi) potential for downstream automation of data; (vii) improved customer service, via better visualisation; and, (viii) use of data over the lifecycle of the facility (Azhar 2011).

The term 'Lean Construction' originated from the leadership group of the International Group for Lean Construction (IGLC), when they first met in 1993. It refers to the adaptation of lean thinking started in the Japanese automotive industry into the construction industry and is focused upon better meeting client expectations, whilst using 'less of everything' (Salem et al. 2006; Aziz and Hafez, 2013). Constructing Excellence (2004) state that LC is a philosophy that is derived from the concepts of lean manufacturing. The approach seeks to better manage the construction process towards meeting the expectations of the customer. A number of core principles underlie the philosophy: (i) eliminate waste and variability; (ii) precisely specify value from the perspective of the ultimate customer; (iii) clearly identify the process that delivers what the customer values (the value stream) and eliminate all non-value adding steps; (iv) make the remaining value adding steps flow without interruption by managing the interfaces between different steps; (v) let the customer pull – don't make anything until it is needed, then make it quickly; and, (vi) pursue perfection by continuous improvement (Koskela, 1997). To operationalise the philosophy, some techniques like the Last Planner System (Ballard

2000; Viana et a. 2017), step-wise process improvement (*kaizen*) (Yu et a. 2011), Visual Management (VM) (Tezel et al. 2015), value stream mapping (VSM) (Rosenbaum et a. 2013), Just-in-Time (JIT) logistics (Pheng and Chuan 2001) are used within LC.

With low industry entrance barriers, increasing specialisation and subcontracting practices in project delivery, the importance of SMEs is on the rise in the construction industry (Langford and Male 2008; Teriö and Kähkönen 2011; Hampson et al. 2014; Upstill-Goddard et al 2016). This also gives rise to the argument that in order to fully penetrate and exploit the potential of innovative developments in construction such as LC and BIM special attention should be given to SMEs (Upstill-Goddard et al. 2016; Dainty et al. 2017; Lam et al. 2017; Tezel et al. 2018). There is also a lack of systematic study of the current LC and BIM literature from the SMEs perspective. The aim of the paper is therefore to analyse and discuss the peer-reviewed LC and BIM literature from an SMEs point of view through a systematic literature review.

2. BIM and lean construction at SMEs

Compared to large organisations, SMEs usually lack the personnel, finance and knowledge relevant to adopting new technology with effective strategies of development (Caskey et al. 2001; Hosseini et al. 2016; Lam et al. 2017). According to Arayici et al (2011a), the size of the organisations implementing BIM is a significant factor as it is easier to implement BIM within client or supply side SMEs but it may be beyond the reach of some SMEs due to its cost and knowledge requirements. However, a survey conducted by Eadie et al. (2013) in the UK indicated that although it is not straightforward to implement the BIM process at SMEs, the cost of that implementation is not seen as the most important barrier. Typically, the proportion of large companies adopting BIM is three times more than smaller ones in North America, the former making up 74% in 2009 and this figure continuing to rise up to 91% in 2012, whereas

BIM adoptions in small firms are just around 25% in 2009, followed by small to medium firms which account for 41% (SmartMarket Report 2012).

BIM at SMEs has not received enough attention by policy makers, the industry, and the research community (Dainty et al. 2017; Lam et al. 2017), which causes the lack of the SMEs perspective in the current BIM scene. As a result, SMEs have not fully recognised the benefits of using BIM in project delivery (Poirier et al. 2015; Hosseini 2016). This, as a field of study, has also attracted little attention, which is reflected in the limited number of publications that directly reference the use of BIM within SMEs (Love and Irani 2004; Dainty et al. 2017). One reason for this is that the unit of analysis in many works is the project itself; not the organisation. SMEs are very dependent on other stakeholders on getting a BIM model to use, in any bigger projects where they are subcontractors, which necessitates research across those stakeholders (Sebastian et al. 2009; Arayici et al. 2011a; Succar and Kassem 2015). Then there are smaller projects where an SME is the main contractor or developer, which allows for a more focused study within the SME, without needing as much stakeholder input (Barrett and Sexton 2006; Hosseini et al. 2016). It emerges that SMEs are pessimistic about BIM and consider that BIM discriminates against small independent practices in the construction industry, notwithstanding the fact that BIM implementation could be more easily achieved in SMEs in comparison to larger organisations (NBS 2015).

Similarly, LC at SMEs has also attracted little attention from researchers, evidenced by the limited number of publications that directly reference the use of LC within SMEs. It was noted that adoption of innovative management practices, such as lean thinking in the discontinuous and project-based construction industry is problematic (Höök and Stehn 2008; Singh et al. 2012; Dallasega et al. 2015). Mossman (2009) suggests that medium sized companies are

playing a leadership role in introducing LC but that adoption is piecemeal and haphazard. Tezel et al. (2018), discussing LC implementation barriers in the specific context of construction SMEs, suggest the principal barriers to lean in SME firms are: (i) the finances of SMEs do not permit much investment in innovation; (ii) SMEs do not trust their larger clients sufficiently to partner for LC; (iii) there is a lack of collaborative supply chain integration, meaning SMEs do not realise any benefits of lean; (iv) a general scepticism that mutual benefits will come from collaborative or other business improvement initiatives; and, (v) the lack of client support/imperative to help develop lean capabilities within their SME suppliers.

Increasing BIM and LC adoption amongst SMEs is a key condition for achieving the transformation of the construction industry through BIM and LC (Alves et al. 2012; Dainty et al. 2017; Lam et al. 2017; Tezel et al. 2018). Research is expected to facilitate and to support the dissemination of those concepts among SMEs by providing evidence and guidance to researchers, practitioners and policy makers of the industry. Understanding the characteristics of the current research scene on BIM and LC at construction industry SMEs becomes necessary in this sense. As to our knowledge there is no comprehensive overview of the recent research of BIM and LC in SMEs, the authors try to partly close this gap with the contribution at hand. Adding to the originality of this research, the review presented investigates the literature separately on three levels; (i) LC in SMEs, (ii) BIM in SMEs, and (iii) both LC and BIM in SMEs. The objective of the paper therefore is (i) to offer a state-of-the art review of the recent BIM and LC literature at SMEs in construction research as systematic reviews in this research domain could not be identified by the authors, and (ii) to classify the issues and trends in the literature; and (iii) to provide suggestions for future research and actions.

3. Research method

The method adopted is a systematic literature review of the Lean Construction (LC) and/or Building Information Modeling (BIM) adoption at small and medium-sized enterprises (SMEs) in the construction industry. The systematic literature review is a comprehensive and reproducible method for identifying, evaluating and synthesising the existing body of recorded knowledge produced by researchers, scholars and practitioners (Petticrew 2001; Okoli and Schabram 2010). Systematic literature reviews are essential in generating evidence from existing studies and for their ability to create new knowledge by compiling the existing works, which is essential for directing new research (Denyer and Tranfield 2009; Mostafa et al. 2016). A systematic review aims to reduce bias in selection and inclusion of studies, to appraise the quality of the included studies, and to synthesise them objectively, and transparently by following a replicable review process (Tranfield et al. 2003).

The review covers the literature published in the last 15 years between 2003 – 2018 (April), a period in which both the LC and BIM research domains have visibly matured and attracted significant attention from researchers and practitioners. Also, the authors wanted to maintain the currentness of discussion by covering the most important phases of BIM and LC research, tool development and implementation. The conceptual boundaries of the review were set to include lean thinking as applied in the construction and design of assets (Lean Construction-LC) with inclusion of some major LC techniques such as the Last Planner System, Visual Management, kaizen (continuous improvement), Just-in-Time (JIT), the *kanban* visual controls and so on, BIM, as the process of creating a virtual prototype of an asset and its application in the construction life-cycle, and SMEs in the construction industry.

The review consists of five main steps (Santos et al. 2017): (i) keyword search in the abstracts, titles and/or keywords of publications indexed in the *Scopus, Science Direct, EBSCO, Google*

Scholar and *ICONDA* databases as ; (ii) selection of only peer-reviewed articles published in academic journals and leading conferences; (iii) exclusion of duplicates and articles that do not discuss LC at SMEs, BIM at SMEs or LC and BIM at SMEs at organisational level; therefore, articles discussing the implementation of those concepts only at project level (small or medium-sized projects) were excluded; (iv) selection of the articles that will be included in the review on the basis of being published in a prominent, peer-reviewed medium and written in English; and (v) categorisation and analysis of the articles based on their bibliographic article features and contents. The selected databases index all prominent academic journals and conferences associated with the current LC and BIM research. Also, except for *Google Scholar*, they provide advanced search options to execute robust filtering of publications by the adopted literature search criteria. Review details can be seen in Figure 1.

<Please insert Figure 1 around here>

In the first step of the literature review, the following main keywords were searched in the titles, abstracts and/or keywords of publications in three search rounds:

- 'SMEs' and 'Lean Construction'
- 'SMEs' and 'BIM'
- 'SMEs' and 'Lean Construction' and 'BIM'

Following the initial search of the main keywords, alternative keywords corresponding to each main keyword were also searched in the databases in the same three rounds, replacing the main keywords with the alternatives to ensure an adequate coverage of the literature as different authors may use different wording to denote the same concepts. Alongside the 'SMEs' main keyword, the 'SME', 'micro companies', 'micro organisations', 'micro firms', 'micro enterprises', 'small companies', 'small organisations', 'small firms', 'small enterprises', 'medium sized companies', medium-sized organisations', 'medium-sized firms' and 'medium-

sized enterprises' keywords were also searched as alternatives. For the 'BIM' main keyword, the 'virtual design', 'virtual construction', 'VDC', '3D modelling' and 'Building Information Modeling' keywords were searched as alternatives and alongside the 'Lean Construction' main keyword, the 'Lean', 'Lean Thinking', 'Lean Management', 'Last Planner System', 'Visual Management', 'Kaizen', 'A3', 'PDCA', 'Just-in-Time (JIT)' and 'Kanban' alternative keywords were also investigated. 114 articles were identified after the exclusion of non-peer reviewed publications, articles out of the construction research domain and articles that do not actually discuss or do not mainly focus on LC and/or BIM at SMEs in the construction industry even though they contain those keywords in their titles, abstracts and/or keywords.

There are two main limitations to the selected research method; (i) although non-peer reviewed, published books in the subject area were included in the discussion section of the paper, the systematic review excludes non-peer reviewed and "grey" literature like blogs, websites, notes, social network posts etc., which are extensively used by practitioners interested in LC and BIM as communication media and provide valuable insights related particularly to the current state of implementation of those concepts by the industry, and (ii) the possibility of not including papers that actually contain SMEs related discussions on LC, BIM or both but not explicitly state that in the form of one of the search keywords in their titles, abstracts or keywords. However, systematic literature reviews generally cover peer-reviewed literature as their boundary in academic publications, and should adopt and follow some controllable review inclusion criteria from the outset (Denyer and Tranfield 2009; Booth et al. 2012).

4. Analysis

Analysis of the literature was performed on the bibliographic and content features of the articles. The bibliographic analysis investigates the publication dates, publication types (conference or journal), countries of origin, publication media (name of journals or

conferences) and the top authors of the publications, which follows the bibliographic analysis parameters used by Altay and Green III (2006), Volk et al. (2014) and Santos et al. (2017). The content analysis on the other hand explores the preferred research methods, research foci and content patterns in the literature (Altay and Green III, 2006; Zhou et al. 2013; Santos et al. 2017).

4.1 Bibliographic analysis

When the selected papers were classified by their publication dates and publication types, it was found that the number of publications, and consequently, the interest in SMEs have increased after 2010 (see Figure 2). The number of BIM focused articles (73 in total) outweighs the number of Lean focused (34 in total) and Lean and BIM focused (7 in total) articles (see Table 1). It can be asserted from the initial classification that this surge in the interest in construction SMEs after 2010 has been mainly driven by the BIM and SMEs focused publications and has been in line with the general interest in BIM in the construction industry (see Table 1). Most of the publications in the field are conference articles (74 in total) (see Table 2).

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<Please insert Table 1 around here>

<Please insert Table 2 around here>

By the countries of origin of the first authors of the publications (see Figure 3), the United Kingdom (UK) based academic institutions have produced the highest number of publications since 2003 (39 in total), followed by the Swedish (10 in total), Italian (9 in total), Australian (7 in total) and American institutions (6 in total). The interest in SMEs is rather specific in some countries. For instance, the Australian and Canadian academic institutions have produced only

SMEs and BIM focused research, which is not the case with the SMEs and Lean focused research (see Figure 3).

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As for the publication media of the articles, the annual conference of the *International Group for Lean Construction (IGLC)* has been the medium for the highest number of Lean and SMEs focused publications (12 in total). The *Association of Researchers in Construction Management (ARCOM)* conference, on the other hand, has been the medium for the highest number of BIM and SMEs focused publications (6 in total). The journal *Automation in Construction* contains the highest number of Lean and BIM and SMEs focused articles (2 in total). A more detailed ranking of the top media for the publications can be seen in Table 3.

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As for the most prolific authors in the field, Patrick Dallasega has authored the highest number of Lean and SMEs focused articles (4 in total). On BIM and SMEs, Tahar Kouider has authored the highest number of articles (5 in total). Yusuf Arayici and Paul Coates have both authored the highest number of SMEs and Lean and BIM focused articles (3 in total). A more detailed ranking of the most prolific authors can be seen in Table 4. In terms of number of citations on Google Scholar, Yusuf Arayici has the most citations (550) for his Lean and BIM and SMEs focused articles. Robert Eadie follows Yusuf Arayici with 348 citations for his BIM and SMEs focused article. A more detailed ranking of the most cited authors can be seen in Table 5. A detailed list of most cited publications can be seen in Table 6.

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299

300 *4.2 Content analysis*

301 The majority of the research in the field is empirical (95 in total). The most popular
302 research approach in the SMEs and Lean focused articles is conducting case studies (11 in
303 total), followed by pilot implementations (10 in total). As for the SMEs and BIM focused
304 articles, the most preferred approach to research has been conducting surveys (26 in total),
305 followed by case studies (18 in total). In the SMEs and Lean and BIM focused articles, pilot
306 implementations have been adopted the most (4 in total). A detailed analysis of the preferred
307 research approaches in the field can be seen in Table 7 and Figure 4.

308 <Please insert Table 7 around here>

309 <Please insert Figure 4 around here>

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311 The SMEs and Lean focused articles have concentrated mostly on construction SMEs through
312 demonstrating and discussing the applicability of LC and its associated concepts (23 in total).
313 The SMEs and BIM related articles have discussed and analysed BIM adoption conditions and
314 readiness mostly through BIM enablers and barriers at SMEs with a whole supply chain
315 perspective (31 in total). The SMEs and Lean and BIM focused papers have mostly focused on
316 the adoption of LC and BIM at design SMEs by demonstrating how adopting the BIM process
317 can facilitate the LC ideals (3 in total). A detailed classification of the concentration of the
318 articles by different supply chain roles can be seen in Figure 5.

319 <Please insert Figure 5 around here>

320

321 The content analysis of the articles revealed that there were some content clusters in the SME
322 focused publications (see Table 8). The content cluster that contains most of the publications
323 (20 in total) from the SMEs and BIM focused articles is the BIM readiness and future actions

for SMEs content cluster, which is followed by the publications primarily discussing BIM implementation processes and factors at SMEs (17 in total). The cloud computing and BIM content also comes to fore in this article focus group (7 in total) with just one publication mainly discussing BIM training issues for smaller companies. Among the SMEs and LC focused articles, the content cluster that contains most of the publications (15 in total) is the LC techniques implementation cluster, in which authors describe the implementation of a LC technique(s) at SMEs. This popular content cluster is followed by the publications primarily evaluating LC implementation conditions and prescribing future actions for LC in SMEs (8 in total). In the SMEs and LC and BIM focused articles, the content cluster that contains most of the publications (4 in total) is the effect of BIM implementation on achieving LC targets cluster, in which authors discuss and demonstrate how BIM can facilitate LC principles and implementation at SMEs. This content cluster is followed by the publications (2 in total) primarily evaluating BIM and LC applicability and readiness for SMEs.

<Please insert Table 8 around here>

The content clusters were also examined by the publication's main research methods (see Table 9). According to this examination, it was found that BIM readiness, BIM barriers and BIM implementation processes/factors at SMEs had been mostly explored in the literature using surveys. In the SMEs an LC focused articles, case studies and pilot implementations were conducted mostly to demonstrate the implementation of a LC technique(s) at SMEs. In the SMEs and LC and BIM publications, pilot implementations in the BIM process at SMEs were preferred to explore the effect of BIM on achieving LC targets.

<Please insert Table 9 around here>

5. Discussion

5.1 SMEs and BIM

The reviewed SMEs literature has mainly focused on BIM. Papers and researchers from the SMEs ad BIM domain have also collected a larger number of citations as seen from Table 5 and Table 6. This is in line with the current BIM-hype in the construction industry (Fox 2014; Dainty et al. 2015). Much of the contemporary BIM research tends to promote rational and positivistic perspectives of BIM, often focused on its revolutionary promises for increased efficiency (Miettinen and Paavola 2014; Dainty et al. 2015; Yalcinkaya and Singh 2015; Vass and Gustavsson 2017). Other remedies for the industry such as total quality management (TQM) (continuous improvement and quality control principles), LC and partnering (supply chain alliancing) did not have the same industry-wide influence on industry discourse as BIM (Green, 2011). According to Dainty et al. (2017), part of this support for BIM is down to its materiality, rendering it different from other initiatives such as partnering and LC in having a technological substance that can be represented physically and rationally as an object. However, in many of the existing publication in the BIM and SMEs research, the focus of discussions is not mostly on SMEs but SMEs are discussed to varying depth as part of larger BIM implementation discussions.

On the positive side, the interest in BIM at smaller firms specifically seems to have been on the rise in the literature as overlooking SMEs in the BIM agenda will exacerbate the existing digital divide between large and small organisations in the construction industry (Epstein et al. 2011; Taylor 2015; van Deursen and van Dijk 2015). The UK-based institutions dominate the discussion on BIM and SMEs. This can be partly attributed to the mandated use of BIM in publicly procured building projects in the country and coming to the realisation of practical difficulties associated with operationalising the mandate and policy implementation without involving SMEs, particularly beyond large and signature projects. There are some initiatives

374 facilitating BIM at SMEs in the UK, such as knowledge-transfer partnerships (KTPs), taking
375 place at SMEs (e.g. Arayici et al. 2011a), and the national BIM Task Group's advice forums
376 (e.g. BIM4SME) to support the argument that SMEs are pivotal for BIM policy
377 implementation, but important decision details regarding SMEs' impact on and how, when and
378 why SMEs are engaged in the BIM policy process are unclear (Dainty et al. 2017).
379
380 Content-wise, the literature seems to be in agreement with the assertion that BIM uptake is
381 more problematic for smaller firms that do not possess the resources or capacity to invest in
382 the BIM process (Eadie et al. 2013; Poirier et al. 2015a; Hosseini et al. 2016; Lam et al. 2017)
383 Consequently, many of the technology-oriented publications propose more affordable and
384 accessible cloud-computing and subscription based models to facilitate SMEs' utilisation of
385 BIM (Jardim-Goncalves and Grilo 2010; Curry et al. 2013; Polter et al. 2014; Adamu et al.
386 2015). A significant portion of the SMEs and BIM focused literature is concerned with
387 descriptive research exploring the barriers before BIM or evaluating the BIM readiness of
388 construction supply chains in different countries by describing the status-quo in terms of BIM.
389 However, how those descriptive studies inform the BIM policies toward SMEs in their
390 countries is not clear. Those barriers before BIM at SMEs were identified commonly by many
391 (Michaloski and Costa 2010; Arayici et al. 2011a, 2011b; Ku and Taiebat 2011; Gledson et al.
392 2012; Hong et al. 2016; Hosseini et al. 2016; Monozam et al. 2016; Lam et al. 2017): (i) cost
393 and time constraints, (ii) lack of experienced and skilled personnel, (iii) overall understanding
394 of BIM, (iv) lack of data on Return on Investment of BIM and its perceived usefulness, (v)
395 others' capability to collaborate, (vi) software related issues (e.g. interoperability, maintenance,
396 operation ease), (vii) procurement, contract and standards related issues (e.g. model ownership,
397 intellectual rights, finding optimum procurement arrangements), and (viii) management
398 commitment/leadership.

Only one conference publication briefly discussing formal BIM training with a subtle emphasis on SMEs was identified (Udeaja and Aziz 2015). Therefore, it can be concluded that there is a need to better understand and develop multi-layered BIM training mechanisms and diffusion models for different SME company sizes (micro to medium-sized). Detailed conceptual discussions on these, followed by pilot implementations, which seem to have been among the lesser preferred research methods in the BIM and SMEs focused publications, are required. Also, this differentiation in company sizes among SMEs is necessary in understanding organisational BIM diffusion parameters and in expanding BIM benefits discussions, demonstrating different benefits or returns of investment of BIM by different SME types. Research exploring the BIM diffusion interfaces and mechanism (e.g. procurement, training, incentives, know-how and technology transfer) (Succar and Kassem 2015) from an SMEs perspective between clients, larger companies, and SMEs, and the BIM diffusion interfaces among SMEs themselves in different construction sectors' supply chains should increase.

5.2 SMEs and LC

The LC and SMEs focused publications group contains less than half as many of the number of publications as in the SMEs and BIM focused publications group. There is no visible trend over time in terms of increase or decrease in the number of publications, resulting in a more consistent publication output numbers year-on-year. There is also no significant difference between the UK, Swedish, Italian, American and Brazilian institutions in this research focus group in terms of research output. Therefore, it is not possible to claim that institutions from a specific country dominate the research scene. One notable trend in the SMEs and LC focused literature is that an overwhelming majority of the publications in this group are concerned with construction SMEs rather than design SMEs. There are several works in

424 the LC literature discussing the applicability of LC principles and techniques in design
425 processes (Hamzeh et al. 2009; Zimina et al. 2012; Tauriainen et al. 2016). Despite this, the
426 current discussion on LC adoption form the design SMEs' perspective is very limited.
427
428 Another notable trend in this group is that almost half of the publications' media have been the
429 International Group for Lean Construction's (IGLC) annual conference and the Lean
430 Construction Institute's Lean Construction journal. This concentration of publications around
431 a few media can be a limitation for this research focus as it may negatively affect the access
432 rate of the SMEs and LC research. Although there are no barriers to entry for the larger research
433 community, such implicit, closed community feeling in the LC research scene was subject to
434 criticism before (Green, 1999; Green et al. 2005; Jørgensen and Emmitt 2008). More diversion
435 in publication media is deemed useful for further dissemination of this research focus.
436
437 It should also be highlighted that although some client-driven contractual LC obligations
438 imposed on construction supply chains do exist (e.g. highways supply chain in the UK) (Tezel
439 et al. 2018), currently, there are no government-driven mandates and no large-scale support
440 groups targeting specifically SMEs for LC implementations like the BIM implementation
441 scene in the UK. In short, LC does not enjoy the same hype, attention and organised
442 government support as BIM in some countries, and this is also reflected in the literature.
443 Formation of such support groups for LC at SMEs at the sectoral or national level can be useful
444 for an increased uptake of LC by construction industry SMEs. However, it is also down to the
445 LC community to create this attention by demonstrating the business case and diffusion
446 mechanisms for LC at SMEs (Alves et al. 2012).
447

448 Much of the current discourse in the LC literature involves the demonstration of the
449 implementation of a LC technique(s) at SMEs through pilot implementations and case studies.
450 This operational lens to LC is commonplace in the literature. As a result, alongside the
451 insufficient theoretical exploration of LC and the positive bias sensed in the research tone of
452 the LC research community, one of the criticisms of the current LC discourse is that it mostly
453 overlooks organisational, procurement, training and project governance related parameters in
454 LC implementations (Green et al. 2005; Jørgensen and Emmitt 2008; Alves et al. 2012;
455 Wandahl 2014; Cano et al. 2015). In other words, the current LC discussion can be criticised
456 for giving due regard to the specific context of construction and its supply chain conditions.
457 The authors assert that this criticism applies to the SMEs and LC focused literature as the
458 organisational parameter of the companies' being SMEs has generally had little to no effect on
459 the discourse in the publications. Hence, it is hard for the reader to pinpoint detailed
460 clarifications as to the effect of the subject organisations' being SMEs in those implementations
461 and what to do to achieve a deeper penetration of LC in SMEs. Similar to the SMEs and BIM
462 focused literature, discussions around LC training and diffusion mechanisms at SMEs are
463 currently very limited. Research should be conducted toward creating a sector-wide LC
464 implementation strategy to inform future policies, which do not exist for LC at the moment.
465 Furthermore, there are only a few works concerned with theoretical exploration of LC at SMEs.
466
467 *5.3 SMEs and LC and BIM*
468 Synergies between LC and BIM, which are mostly positive, have been underlined for a
469 while (Sacks et al. 2010; Arayici et al. 2011a; Hamdi and Leite 2012; Dave et al. 2013; Al-
470 Hattap and Hamzeh 2015). There are also attempts to extend BIM capabilities (e.g. VisiLean)
471 to support some LC techniques (e.g. the Last Planner System) (Dave et al. 2011; Gurevich and
472 Sacks 2013). Despite this, very little research investigating the combined implementation of

LC and BIM from an SMEs perspective can be found in the literature. Moreover, the existing pilot implementation discussions, which are the outcomes of a single KTP project in the UK, focus on design SMEs, in which the BIM implementation is the main subject of interest with some discussions around how BIM can facilitate LC goals (Arayici et al. 2011a; 2011b). Despite the secondary LC focus, the two publications from that KTP project rendered Yusuf Arayici, as the primary author of those publications, the most cited researcher in the field (see Table 5 and Table 6), indicating an interest in this research focus.

This paucity in research can be partly attributed to the increased complexity of the subject focus involving the implementation of both BIM and LC at SMEs, most of which are already struggling with successfully taking on even one of those concepts (Dainty et al. 2017; Tezel et al. 2018). Also, the misinterpretation that LC, as a more management focused concept, and BIM, as a more technology-oriented concept, are disconnected research domains, and the limited number of researchers who are interested in both BIM and LC are exacerbating this lack of research activity. Scarcity of theoretical discussions is conspicuous in this research focus group. The authors assert that research focusing on the combined implementation of BIM and LC should increase with more attention to construction SMEs, alongside design SMEs, through case studies and pilot implementations. Also, theoretical works critically exploring BIM and LC implementation parameters, frameworks, diffusion models, training mechanisms, and critical success factors at SMEs are required.

Even though non-peer reviewed, recent books in the LC and BIM domains by prominent authors were also reviewed to check their content for SMEs (see Table 8). Of the reviewed 28 books, only 1 book (Harty et al. 2015) from the BIM domain contains significant discussions for SMEs. There are also 3 other books (Levy 2012; Klaschka 2014; Mordue and Finch 2014

) again from the BIM domain discussing the implementation of the BIM process in small practices and projects, which cannot be directly categorised as SMEs related. The book review validates that in spite of the recent rise in the interest in small-scale projects, particularly in the BIM domain, the contents of books' narratives are mostly generic without a significant SMEs focus.

<Please insert Table 8 around here>

A summary of the main practice and research related findings after the systematic analysis of the peer-reviewed literature and the book review for each focus (LC and SMEs, BIM and SMEs, BIM and LC and SMEs) can be seen in Table 9. The findings suggest that there are still relatively fewer discussions mainly focusing on SMEs in the peer-reviewed academic media and in books on LC and BIM, calling for the attention of research community to this key group in construction supply chains. Beyond specific implementation cases at some SMEs or more descriptive works discussing the as-is situation of LC and/or BIM in specific countries or sectors, it is deemed that research and implementation on regional or sector-wide training and diffusion mechanisms including procurement for LC and/or BIM at SMEs will have a higher practical impact. These can be developed through collaborative efforts between academia and policy makers. A narrative highlighting the combined implementation of LC and BIM in the industry should be instilled through modifying university curricula, introducing on-the job training programmes, and encouraging/demanding consultation services for the combined implementation of LC and BIM. This will challenge the misinterpretation that LC and BIM should be treated separately. In this regard, LC can be incorporated in BIM soft-landing strategies as well as SME-focused task forces for BIM. Research community should support these practical efforts that should be initiated by companies and policy makers by providing

522 the business case and offering implementation mechanisms, frameworks and implementation
523 support for Lean and BIM at SMEs.

524 <Please insert Table 9 around here>

525 **6. Conclusion**

526 The panorama of the current LC and BIM literature toward SMEs was discussed in this
527 paper. Despite the hype, investigations show that the wholesale uptake of BIM and LC at SMEs
528 is problematic. It is not possible to realise the rhetorical promises of BIM and LC, two of the
529 prominent concepts challenging the traditional practices in construction management, without
530 giving sufficient consideration to SMEs. This accentuates especially when in many countries
531 there are policy initiatives towards improving productivity in the construction industry. In spite
532 of the well-known importance of SMEs, the less powerful and influential actors that account
533 for the vast majority of firms operating in the construction industry, the current literature on
534 LC and BIM at SMEs falls short in terms of both number of publications and depth of
535 discussions in those publications. Detailed analyses in journal articles on the implementation
536 of these concepts in SMEs are even more scarce. Accounts on the combined implementation
537 of LC and BIM at SMEs are virtually non-existent. Additionally, discussions around the
538 application of those concepts in small practices or small-scale projects cannot equate to detailed
539 investigations of those concepts from an SMEs perspective.

540

541 There are some commonalities in the contents of the LC and BIM literature concerned with
542 SMEs. No differentiation in the literature between micro, small and medium sized companies,
543 and over different supply chain characteristics of different construction sectors (e. g. building,
544 civil, industrial/energy etc.), in which SMEs operate, was found. This creates a situation of
545 oversimplification, in which different types of firms operating in different supply chain realities
546 are tossed into the same SMEs bag. Also, in several instances, the literature reviewed had no

clear SME focus, other than that a small or medium company had taken part in the primary research at some level. In such papers, the authors do not differentiate that the focus of the paper has any particular relevance to the size of the firm being studied.

A more critical and SME-focused research agenda is now required that explores the diffusion mechanisms of the BIM and LC concepts across the varying institutional factors shaping their implementations at SMEs. Given that BIM and LC have been studied since the 1990s, it is perhaps surprising that so few have reflected on their combined implementation in the SMEs context. A deeper understanding of this combined implementation of BIM and LC therefore requires solid reflections on the processes, technology and diffusion mechanisms to inform practitioners and policy makers of the industry. To overcome the limitations of this study in terms of covering the "grey" or non-peer reviewed literature, a synthetic literature review covering both peer-reviewed and non-peer reviewed literature can be conducted in the future.

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872 **Figure Legend**

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883 **Table 1. Detailed list of number of publications by year, publication type and**
884 **publication focus**

Year and publication type	Publication focus		
	SMEs and Lean	SMEs and BIM	SMEs and BIM and Lean
2004	**1**		
Conference paper	1		
2005	**1**		
Journal paper	1		
2006	**1**		
Conference paper	1		
2007	**2**	**1**	
Conference paper	1	1	
Journal paper	1		
2009		**1**	
Conference paper		1	
2010	**4**	**4**	
Conference paper	2	2	
Journal paper	2	2	
2011	**2**	**3**	**3**
Conference paper	2	3	1
Journal paper			2
2012	**3**	**4**	**1**
Conference paper	2	3	1
Journal paper	1	1	
2013	**4**	**9**	
Conference paper	2	5	
Journal paper	2	4	
2014	**3**	**9**	
Conference paper	3	8	
Journal paper		1	
2015	**3**	**15**	
Conference paper	3	10	
Journal paper		5	
2016	**4**	**15**	**1**
Conference paper	4	11	
Journal paper		4	1
2017	**4**	**8**	**1**
Conference paper	2	4	1
Journal paper	2	4	
2018	**2**	**4**	**1**
Journal paper	2	4	1
Grand Total	**34**	**73**	**7**

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888 **Table 2. Summary of number of publications by publication type and focus**

Publication type	Publication focus			
	SMEs and Lean	**SMEs and BIM**	**SMEs and BIM and Lean**	**Grand Total**
Conference paper	23	48	3	**74**
Journal paper	11	25	4	**40**
Grand Total	**34**	**73**	**7**	

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891 **Table 3. Top publication media (conferences or journals) by number of publications and publication focus**

No	Top journals/conferences (overall)		Top journals/conferences by article focus					
			Lean and SMEs		BIM and SMEs		Lean and BIM and SMEs	
	Journals/conferences	Number of articles	Journals/conferences	Number of articles	Journals/conferences	Number of articles	Journals/conferences	Number of articles
1	International Group for Lean Construction (IGLC) Conference	12	International Group for Lean Construction (IGLC) Conference	12	Association of Researchers in Construction Management (ARCOM) Conference	6	Automation in Construction (Journal)	2
2	Association of Researchers in Construction Management (ARCOM) Conference	7	Lean Construction Journal (Journal)	3	International Congress of Architectural Technology (ICAT)	4	Creative Construction Conference	1
3	Automation in Construction (Journal)	5	Other	19	International Symposium on Automation and Robotics in Construction	4	Structural Survey (Journal)	1
4	International Congress of Architectural Technology (ICAT)	4			Automation in Construction (Journal)	3	International Journal of 3-D Information Modeling (Journal)	1
5	International Symposium on Automation and Robotics in Construction	4			International Council for Building - Information Technology for Construction Conference (CIB W78)	3	FIATECH (Conference)	1
6	International Council for Building - Information Technology for Construction Conference (CIB W78)	3			Other	53	Business Computing and Global Informatization (Conference)	1
7	Lean Construction Journal (Journal)	3						
8	Other	76						

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893 **Table 4. Most prolific authors by number of publications and publication focus**

No	Top authors (overall)		Top authors by article focus					
			Lean and SMEs		BIM and SMEs		Lean and BIM and SMEs	
	Author name	Number of articles	Author name	Number of articles	Author name	Number of articles	Author name	Number of articles
1	Tahar Kouider	5	Patrick Dallasega	4	Tahar Kouider	5	Yusuf Arayici	3
2	Lauri Koskela	4	Jarkko Erikshammar	3	Reza Hosseini	4	Paul Coates	3
3	Sheryl Staub-French	4	Stephen Emmitt	2	Sheryl Staub-French	4	Lauri Koskela	2
4	Patrick Dallasega	4	Algan Tezel	2	Daniel Forgues	4	Others	11
5	Reza Hosseini	4	Zeeshan Aziz	2	Erik Poirier	4		
6	Daniel Forgues	4	Lauri Koskela	2	Others	172		
7	Erik Poirier	4	Others	82				
8	Others	277						

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896 **Table 4. Most cited authors by publication focus**

No	Author	Total number of citations on Google Scholar by research focus			
		SMEs and BIM	SMEs and BIM and Lean	SMEs and Lean	Total
1	Yusuf Arayici		550		550
2	Robert Eadie	348			348
3	Ossama Salem			154	154
4	Edward Curry	121			121
5	Erik Poirier	103			103
6	Ricardo Jardim-Goncalves	84			84
7	Roshana Takim	62			62
8	Anoop Sattineni	56			56
9	Francisco Ribeiro			52	52
10	Rizal Sebastian	49			49

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Table 5. Most cited publications

No	Publication name	Authors	Publication year	Publication medium	Publication type	Empirical or Theoretical	Primary research method	Research focus	Number of citations on Google Scholar	Comments
1	BIM implementation throughout the UK construction project lifecycle: An analysis	Eadie et al.	2013	Automation in Construction	Journal paper	Empirical	Survey	SMEs and BIM	348	SMEs are discussed as part of a larger BIM implementation discussion.
2	Technology adoption in the BIM implementation for lean architectural practice	Arayici et al.	2011	Automation in Construction	Journal paper	Empirical	Pilot Implementation	SMEs and BIM and Lean	345	It is mostly focused on BIM with secondary discussions on LC at SMEs.
3	BIM adoption and implementation for architectural practices	Arayici et al.	2011	Structural Survey	Journal paper	Empirical	Pilot Implementation	SMEs and BIM and Lean	191	It is mostly focused on BIM with secondary discussions on LC at SMEs.
4	Site implementation and assessment of lean construction techniques	Salem et al.	2005	Lean Construction Journal	Journal paper	Empirical	Case study	SMEs and Lean	154	LC techniques are discussed for medium-sized organisations in particular
5	Linking building data in the cloud: Integrating cross-domain building data using linked data	Curry et al.	2013	Advanced Engineering Informatics	Journal paper	Empirical	Pilot Implementation	SMEs and BIM	121	Cloud-based system implementation at an SME.
6	SOA4BIM: Putting the building and construction industry in the Single European Information Space	Jardim-Goncalves and Grilo	2010	Automation in Construction	Journal paper	Theoretical	Conceptual Discussion	SMEs and BIM	84	SMEs are discussed as part of a larger BIM implementation and e-business discussions.
7	Building Information Modeling (BIM): A new paradigm for quality of life within architectural, engineering and construction (AEC) industry	Roshana Takim et al.	2013	AMER International Conference on Quality of Life	Conference paper	Empirical	Workshops/Focus groups	SMEs and BIM	62	SMEs are discussed as part of a larger BIM implementation discussion.
8	Estimating with BIM: A survey of US construction companies	Sattineni and Bradford	2011	International Symposium on Automation and Robotics in Construction	Conference paper	Empirical	Survey	SMEs and BIM	56	SMEs are discussed as part of a larger BIM implementation discussion.
9	Exploring agile methods in construction small and medium enterprises: A case study	Ribeiro and Fernandes	2010	Journal of Enterprise Information Management	Journal paper	Empirical	Case study	SMEs and Lean	52	SMEs are the primary focus of the paper.
10	Modelling the costs of corporate implementation of building information modelling	Olatunji, O.A.	2011	Journal of Financial Management of Property and Construction	Journal paper	Empirical	Workshops/Focus groups	SMEs and BIM	44	SMEs are the primary focus of the paper.

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903 **Table 6. Detailed classification of research approach and methods by publication**
904 **numbers and publication focus**

Empirical or Theoretical/ Main research method	Article focus			Grand total
	SMEs and Lean	SMEs and BIM	SMEs and BIM and Lean	
Empirical	**29**	**59**	**7**	**95**
Case study	11	18	3	32
Interview	2	2		4
Pilot implementation	10	9	4	23
Survey	5	26		31
Workshops/Focus groups	1	4		5
Theoretical	**5**	**14**		**19**
Conceptual discussion	3	11		14
Literature review	1	3		4
Prototype or model presentation	1			1
Grand Total	**34**	**73**	**7**	**114**

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908 **Table 7. Detailed classification of publication contents by publication focus**

Publication focus / Content	No of publications	Examples from the literature
SMEs and BIM	**73**	
Barriers before BIM	12	Charlson and Oduoza (2014)
BIM and energy simulation	2	Stojanovic et al. (2014)
BIM implementation benefits and risks	12	Poirier et al. (2015b)
BIM implementation process/factors	17	Hosseini et al. (2016)
BIM readiness and future actions	20	Dainty et al. (2017)
BIM training	1	Udeaja and Aziz (2015)
Cloud computing based collaboration/integration models	7	Adamu et al. (2015)
Reality capture (remote sensing) evaluation	1	Craggs et al. (2016)
Visual query language	1	Wülfing et al. (2014)
SMEs and Lean	**34**	
IT systems to support LC	3	Azambuja et al. (2013)
LC evaluation and future actions	8	Tezel et al. (2018)
LC implementation model	5	Erikshammar et al. (2014)
LC technique implementation	15	Emmitt et al. (2012)
LC training	3	Alves et al. (2016)
SMEs and BIM and Lean	**7**	
Cloud computing and Internet of Things (IoT) to support LC and BIM	1	Xu et al. (2018)
Effect of BIM implementation on achieving LC targets	4	Arayici et al. (2011a)
Evaluation of the applicability of and readiness for LC and BIM	2	Hao (2012)
Grand Total	**114**	

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Table 8. Detailed classification of publication contents by main research method

Publication focus / Content	Main research method								
	Case study	**Conceptual Discussion**	**Interview**	**Literature review**	**Pilot Implementation**	**Prototype or model**	**Survey**	**Workshops/Focus groups**	**Grand Total**
SMEs and BIM	**18**	**11**	**2**	**3**	**9**		**26**	**4**	**73**
Barriers before BIM	2		1				9		12
BIM and energy simulation		1			1				2
BIM implementation benefits and risks	4	1			4		2	1	12
BIM implementation process/factors	5	1	1		2		7	1	17
BIM readiness and future actions	5	2		3			8	2	20
BIM training	1								1
Cloud based collaboration/integration models		5			2				7
Reality capture	1								1
Visual query language		1							1
SMEs and BIM and Lean	**3**				**4**				**7**
Cloud and IoT to support LC and BIM					1				1
Effect of BIM implementation on achieving LC targets	1				3				4
Evaluation of the applicability of and readiness for LC and BIM	2								2
SMEs and Lean	**11**	**3**	**2**	**1**	**10**	**1**	**5**	**1**	**34**
IT to support LC					2		1		3
LC evaluation and future actions	3	1	2	1			1		8
LC implementation model		2			1	1	1		5
LC technique implementation	7				7		1		15
LC training	1						1	1	3
Grand Total	**32**	**14**	**4**	**4**	**23**	**1**	**31**	**5**	**114**

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Table 9. Review of recent books on BIM and Lean Construction

No	Authors	Year	Book's domain		Comments
			BIM	LC	
1	Arayici et al.	2017	Yes	NA	No SMEs focus
2	Pittard and Sell	2017	Yes	NA	No SMEs focus.
3	Sacks et al.	2017	Yes	Yes	No SMEs focus.
4	Eynon	2016	Yes	NA	This book has no particular SMEs focus. SMEs are mentioned 5 times, mainly in the context of how BIM can empower SMEs to compete on a larger stage.
5	Holzer	2016	Yes	NA	No SMEs focus
6	Sanchez et al.	2016	Yes	NA	No SMEs focus
7	Barnes and Davies	2015	Yes	NA	No SMEs focus
8	Emuze and Saurin	2015	NA	Yes	No SMEs focus
9	Hardin and McCool	2015	Yes	NA	No SMEs focus
10	Harty et al.	2015	Yes	NA	Specifically aimed at SMEs, directed focus throughout is the particular issues of SMEs in adopting BIM.
11	Shepherd	2015	Yes	NA	No SMEs focus
12	Gao and Low	2014	NA	Yes	No SMEs focus
13	Klaschka	2014	Yes	NA	This book provides case studies of BIM use in small architectural practices
14	Mordue and Finch	2014	Yes	NA	Some of the examples given in mini case studies cover small projects/situations. Others, cover large projects. No obvious focus on SMEs..
15	Crotty	2013	Yes	NA	No SMEs focus
16	Levy	2012	Yes	NA	This book is focused in small projects rather than specifically small contractors or designers. However, given nature of projects, small companies are mentioned several times in the context of them carrying out the projects
17	Race	2012	Yes	NA	No SMEs focus
18	Deutsch	2011	Yes	NA	No SMEs focus
19	Eastman et al.	2011	Yes	NA	No SMEs focus
20	Terry and Smith	2011	NA	Yes	No SMEs focus
21	Forbes and Ahmed	2010	NA	Yes	No SMEs focus
22	Patty et al	2009	NA	Yes	No SMEs focus
23	Smith and Tardiff	2009	Yes	NA	No SMEs focus.
24	Underwood	2009	Yes	NA	No SMEs focus.
25	Cain	2008	NA	Yes	No SMEs focus
26	Krygiel and Nies	2008	Yes	NA	No SMEs focus.

27	O’Brien et al.	2008	NA	Yes	No SMEs focus
28	Jernigan	2007	Yes	NA	No SMEs focus

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914 **Table 9. Research findings and implications**

Domain	Research related findings	Practice related findings
SMEs and BIM	• Most of the reviewed publications are from this domain. • This research domain has gained more interest after 2010 with a visible increase in the research output in recent years. • UK-based institutions have notably produced most of the publications in this domain. • There is more diversion in the publication media for this domain when compared to the SMEs and Lean domain. • Surveys and case studies are the most preferred research methods. • BIM readiness and future actions, BIM implementation process/factors, BIM implementation benefits and risks, and barriers before BIM at SMEs have been the most popular research foci. • Studies on BIM training and diffusion mechanisms for SMEs are scarce.	• Most of the works in this domain are based on understanding or revealing the as-is situation for BIM at SMEs within a whole supply chain perspective • It is not clear how these works inform the practical BIM policies and diffusion mechanisms at SMEs in different countries. • The scarcity in research on BIM training and diffusion mechanisms creates a situation where research-based guidance for the BIM process implementation at different sized SMEs operating in different construction sectors is missing. • Works focusing on evaluating the business case for BIM at SMEs with concrete proofs are required. • The cloud computing technology has gained notable interest in this domain as it may offer affordable access to the BIM technology for SMEs in practice.
SMEs and Lean	• There is no visible trend over time in terms of increase or decrease in the number of publications in this domain. • There is no notable country of origin for the publications in this domain. The distribution of countries is more even. • More diversion in the publication media will be useful for a greater dissemination of the domain. • Pilot implementations and case studies are the most preferred research methods. • The most popular research focus has been discussions on the application of a lean technique/techniques at SMEs. • The organisational parameter of the studies companies' being SMEs has generally had little to no effect on the discourse in the publications. • Theoretical works are scarce. • This scarcity in theoretical discussions creates opportunities for research on implementation parameters, frameworks, diffusion models, training mechanisms, and critical success factors for LC at SMEs.	• Lack of research/cases on LC at design SMEs is conspicuous • LC at SMEs research and narrative should go beyond operational practices (LC technique implementation) and focus also on organisational, procurement, training and project governance related parameters in LC implementations • LC does not enjoy the same amount of systematic support as BIM, which reflects in the number of papers and amount of discussions. • Formation of support groups for LC at SMEs at the sectoral or national level will be useful.
SMEs and BIM and Lean	• Research in this domain is very scarce. • This scarcity in theoretical discussions necessitates research on implementation parameters, frameworks, diffusion models, training mechanisms, and critical success factors for LC and BIM at SMEs. • LC has been the secondary focus with the primary focus being BIM at SMEs for the available literature in this domain. • The synergies between Lean and BIM (Sacks et al. 2010) can also be revisited with an SMEs perspective. • Detailed and academically rigorous case investigations and pilot studies involving SMEs from different construction sectors to set examples and to create the business case for the domain are required.	• Misinterpretations of BIM and LC being two disconnected research domains should be challenged. • University curricula can be modified to underline the combined implementation of LC and BIM. • For soft-landing in this domain, LC can be incorporated in BIM soft-landing strategies as well as in SME task forces for BIM. • The LC research community need to be more active in their investigations of LC and BIM with a special focus on SMEs. • An increase in the number of competent consultants with both LC and BIM skills and expertise will be also beneficial to SMEs.

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